Required data	Automated continuous monitoring of ambient air temperature
Data input type	Quantitative
Data collection frequency	Annually; at minimum, before and after NBS implementation
Level of expertise required	Low
Synergies with other indicators	Evaluated from *TX_x, Monthly mean value of daily maximum temperature, TN_n, Monthly mean value of daily minimum temperature*; related to *Warm spell duration index (WSDI)* indicator
Connection with SDGs	SDG 3 Good health and well-being, SDG 11 Sustainable cities and communities, SDG 13 Climate action
Opportunities for participatory data collection	Participatory data collection is feasible through direct temperature measurements if these are not automated
Additional information	
References	http://etccdi.pacificclimate.org/list_27_indices.shtml Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management, 146, 107-115.

2.15 Cooling of ambient air

2.15.1 Air cooling

Project Name: Naturvation (Grant Agreement no. 730243)

Author/s and affiliations: Peter Olsson[1]

[1] *CEC – Centre for Environmental and Climate Research, Lund University, Lund, Sweden*

Air cooling (°C)	**Climate Resilience**
Description and justification	The air cooling indicator measures the lowering of air temperature by a nature-based solutions (NBS). Green and blue infrastructure can cool the air by providing shade and by evapotranspiration, the process by which water is transferred from the land to the atmosphere by evaporating from the soil, water surfaces or plants (e.g., 1). Cooling the air can be a climate action for adaptation to

	a warmer climate, as well as mitigate the negative effects of the urban heat island effect. In a warmer climate, air-cooling can become important for health and well-being, especially in an urban environment that is generally warmer than its surrounding areas (2). Some urban environments may need regenerated nature areas to adapt to a warmer climate or urban heat islands, thus air-cooling may be an important aspect of urban regeneration & development.
Definition	The air cooling indicator measures the lowering of air temperature by a nature-based solutions (NBS).
Strengths and weaknesses	
Measurement procedure and tool	Air temperature can be measured directly in the air but also predicted by models for air temperature close to NBS in cities. Air cooling by NBS has two measurable effects: (A) lowering the air temperature and (B) the decrease of temperature cooling by distance from the NBS. Air cooling effects thus measure or predict temperatures under, next to, or at a distance to a nature-based solution. Generally, efficient cooling distances are within 100 to 150 meters from tree patches (3), while large parks can cool up to 440 meters (4). Blue areas cool air in longer distances, between 350 and 1,500 meters (5). Refined scoring methodology is available (6) and assess the effectiveness of cooling capabilities of different NBS as a function of climate zone, size of area and tree coverage. Research on what types of NBS and their mitigation potential for cooling urban environments has been reviewed (7).
Scale of measurement	The temperature reductions were normalized evenly across scores from 1-5. Score 1 corresponds to <1°C cooling; score 2 to 1-1.7°C cooling; score 3 to 1.7-2.3°C cooling; score 4 to 2.3-3°C cooling and score 5 to >3°C cooling. When data for benefits of an NBS towards an urban challenge was not present in the literature it was denoted as not applicable (NA).
Data source	
Required data	
Data input type	Temperatures
Data collection frequency	
Level of expertise required	

Synergies with other indicators	
Connection with SDGs	*SDGs:* 3, 9 &13
Opportunities for participatory data collection	
Additional information	
References	Gunawardena, K.R, Wells, M.J. & Kershawa. T. (2017) Utilising green and bluespace to mitigate urban heat island intensity, Science of the Total Environment 584–585:1040–1055 Oke, T.R. (1982) The energetic basis of the urban heat island, Quarterly Journal of the Meteorological Society, 108 (455): 1-24 Gargiulo, C. Tulisi, A. and Zucaro, F. (2016) SMALL GREEN AREAS FOR ENERGY SAVING: EFFECTS ON DIFFERENT URBAN SETTLEMENTS, ACE: Architecture, City and Environment = Arquitectura, Ciudad y Entorno, 11 (32): 81-94, DOI: 10.5821/ace.11.32.4659. ISSN: 1886-4805. Doick, K.J., Peace, A. & Hutchings, T.R. (2014) The role of one large greenspace in mitigating London's nocturnal urban heat island, Science of the Total Environment 493:662–671 Du, H., Song, X., Jiang, H., Kan, Z., Wang, Z. & Cai, Y. (2016) Research on the cooling island effects of water body: a case study of Shanghai, China, Ecol. Indic., 67:31-38 Zardo, L., Geneletti, D., Perez-Soba, M. & Van Eupen, M.(2017) Estimating the cooling capacity of green infrastructures to support urban planning, Ecosystem Services 26:225–235 Aleksandrowicz O.R. *et al.* (2017) Current trends in urban heat island mitigation research: Observations based on a comprehensive research repository, Urban Climate 21:1-26 Bowler, D.E, Buyung-Ali, L., KnightA, T.M. & Pullin, S.P. (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence, Landscape and Urban Planning 97(3):147-155 Völker, S., Baumeister, H., Claßen, T., Hornberg, C & Kistemann, T. (2013) Evidence for the temperature-mitigating capacity of urban blue space – a health geographic perspective, Erdkunde 67(4): 355-371 Francis, L.F.M. & Jensen, M.B (2017) Benefits of green roofs: A systematic review of the evidence for three ecosystem services, Urban Forestry & Urban Greening 28:167-176 Ren, Z. *et al* 2013 Estimation of the Relationship between Urban Park Characteristics and Park Cool Island Intensity by Remote Sensing Data and Field Measurement, Forests 4(4):868-886 Wang, C., Wang, Z-H. & Yang, J. (2018) Cooling Effect of Urban Trees on the Built Environment of Contiguous United States, Earth’s Future, 6:1066–1081

	Andreou, E. (2014) The effect of urban layout, street geometry and orientation on shading conditions in urban canyons in the Mediterranean, Renewable Energy, 63:587-596 Žuvela-Aloise, M., Koch R., Buchholz S. & Früh B. (2016) Modelling the potential of green and blue infrastructure to reduce urban heat load in the city of Vienna, Climatic Change 135(3-4):425-438 Gromke, C., Blocken, B., Janssen, W., Merema, B., van Hooff, T., & Timmermans, H. (2015). CFD analysis of transpirational cooling by vegetation: Case study for specific meteorological conditions during a heat wave in Arnhem, Netherlands. Building and Environment, 83,11–26 Chang, C.-R. & M.-H. Li (2014). "Effects of urban parks on the local urban thermal environment." Urban Forestry & Urban Greening 13(4): 672-681 Sponken-Smith, R.A. & Oke, T.R. (1998) The thermal regime of urban parks in two cities with different summer climate, International Journal of Remote Sensing 19 (11):2085-2104 Shashua-Bar, L. and Hoffman, M. (2000) Vegetation as a Climatic Component in the Design of an Urban Street: An Empirical Model for Predicting the Cooling Effect of Urban Green Areas with Trees. Energy and Buildings, 31, 221-235. Du, H., Song, X., Jiang, H., Kan, Z., Wang, Z. & Cai, Y. (2016) Research on the cooling island effects of water body: a case study of Shanghai, China, Ecol. Indic., 67:31-38 Cameron RWF, Taylor JE, Emmett MR (2014) What's 'cool' in the world of green façades? How plant choice influences the cooling properties of green walls. Build Environ 73:198–207 Hoelscher, M.T. *et al* (2014) Quantifying cooling effects of facade greening: Shading, transpiration and insulation, Energy and Buildings 114:283-290

2.15.2 Air temperature reduction

Project Name: CONNECTING Nature (Grant Agreement no. 730222)

Author/s and affiliations: Connop, S[1]., Dushkova, D. [2], Haase, D.[2] and Nash, C.[1]

[1] *Sustainability Research Institute, University of East London, UK*

[2] *Geography Department, Humboldt University of Berlin, Berlin, Germany*

Air temperature reduction (Applied and EO/RS combined)	Climate Resilience
Description and justification	NBS can contribute to reducing air temperature, thus reducing energy demand for cooling and reducing associated carbon emissions. Increasing NBS can reduce local temperatures through evapotranspiration and shading, ameliorating urban heat